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Smart Maritime Management 5.0: Integrating Technology and Humanization in Economic Transformation

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Abstract

Smart Maritime Management 5.0 is a maritime management concept that integrates advanced technology with humanization values to drive sustainable economic transformation. This approach leverages cutting-edge technologies such as the Internet of Things (IoT), artificial intelligence (AI), big data analytics, and automation systems to enhance operational efficiency, navigation safety, and optimal maritime resource management. On the other hand, humanization focuses on strengthening the human role through competency development, welfare improvement, and active participation in strategic decision-making. The integration of technology and humanization not only enhances the competitiveness of the maritime industry but also fosters an adaptive, inclusive, and socially-oriented ecosystem. This study aims to analyze the implementation model of Smart Maritime Management 5.0 and its impact on economic transformation, with a case study in Indonesia's maritime sector.

Keywords smart maritime management 5.0, maritime technology, humanization, economic transformation, internet of things, artificial intelligence, big data, automation, Indonesia.

1. Introduction

The maritime industry constitutes one of the primary pillars of the global economy, given that more than 80% of international trade is conducted via sea routes. Indonesia, as an archipelagic nation with over 17,000 islands, holds a strategic position along international trade routes, positioning it as a global maritime axis. However, the challenges posed by globalization, the advancement of digital technologies, and the growing demand for sustainability necessitate a transformation within the maritime sector one that is smarter, more efficient, and more human-centered. (Bjerkkan, K. Y., & Seter, H, 2020).

The concept of Smart Maritime Management 5.0 emerges as a new paradigm that integrates the principles of the Fifth Industrial Revolution with the specific needs of the maritime sector. While the Fourth Industrial Revolution emphasized automation, the Internet of Things (IoT), big data analytics, and artificial intelligence (AI), the Fifth Industrial Revolution introduces added value through the humanization of technology where the collaboration between humans and machines becomes the key to success (Javaid, M et al., 2021). In the maritime context, this entails the implementation of advanced technologies such as autonomous vessels, blockchain-based shipping documentation, digital twins, and predictive maintenance, accompanied by the enhancement of human resource competencies to operate and manage these

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technologies in an ethical, safe, and sustainable manner (Stopford, M, 2022).

The integration of technology and humanization in the maritime sector serves not only to enhance operational efficiency, but also as a driving force for broader economic transformation (UNCTAD, 2025). The management of smart ports, the digitalization of maritime logistics supply chains, and the implementation of precise marine environmental monitoring systems can foster a more competitive, transparent, and adaptive business ecosystem in response to global market dynamics. Furthermore, this approach can strengthen the competitiveness of Indonesia's maritime industry, reduce national logistics costs, and support an environmentally friendly blue economy agenda (Xu, M., & Yip, T. L, 2021).

Thus, research and discourse on Smart Maritime Management 5.0 become both relevant and crucial. The integration of advanced technologies with a human-centered approach is expected to drive an economic transformation that is inclusive, sustainable, and future-oriented.

2. Literature Review

Concept of Maritime Management 5.0. Maritime Management 5.0 represents a new paradigm in the governance of the maritime sector, combining digitalization, automation, artificial intelligence, big data, and the Internet of Things (IoT) with a human-centered approach. This framework emerges as a response to the Fifth Industrial Revolution, wherein the role of technology is not solely oriented toward efficiency, but also emphasizes human values and sustainability (Bjerkan, K. Y., & Seter, H, 2020). Based on the search results, the term '*Maritime Management 5.0*' has not been extensively or explicitly defined in the available sources. However, it is closely related to the concept of *Society 5.0* or the era of digitalization and technological transformation applied in maritime governance. Maritime Management 5.0 refers to the management of the maritime sector through the utilization of advanced technologies such as the Internet of Things (IoT), artificial intelligence (AI), blockchain, autonomous vessels, and digitalization, which enable more efficient, secure, and sustainable maritime operations. This concept refers to the transformation of maritime governance by integrating technological advancements and digital innovation to address challenges and harness the potential of the oceans. Its primary objectives include enhancing security, safety, operational efficiency, and the sustainable management of marine resources in the era of Society 5.0. Practical applications of this concept include the use of integrated information systems for maritime domain awareness, autonomous vessels for sea transportation, and blockchain technology to ensure transparency within the maritime supply chain.

Integration of Technology in Maritime Management. The integration of technology in maritime management involves the amalgamation of various digital innovations, automation, and intelligent systems into the governance processes of the maritime industry, encompassing shipping, ports, logistics, and maritime security. The primary objective is to enhance operational efficiency, safety, sustainability, and global competitiveness. Below are several key aspects of this integration: (1) Digitalization of Operational Systems – (a) The Electronic Chart Display and Information System (ECDIS) replaces paper charts in ship

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navigation. (b) Digital Twin is used to model the real-time conditions of ships or ports. (c) Smart Port Management Systems are employed to efficiently manage the flow of goods, containers, and vessels. (2) Internet of Things (IoT) and Maritime Sensors – (a) Installation of IoT sensors on vessels to monitor engine conditions, fuel levels, and maritime weather. (b) Data is transmitted to a control center, enabling maintenance to be conducted as predictive maintenance rather than merely reactive. (3) Big Data and Artificial Intelligence (AI) – (a) Big Data analytics is utilized to predict the most efficient routes, operational costs, and logistics demand patterns. (b) Artificial Intelligence (AI) and Machine Learning assist in strategic decision-making, such as optimizing energy usage and detecting potential collisions. (4) Automation and Autonomous Shipping – (a) The emergence of autonomous ships capable of sailing with minimal crew by utilizing AI and navigation sensors. (b) Automated Guided Vehicles (AGVs) at ports are used to transport containers automatically. (5) Blockchain and Logistics Transparency – (a) Blockchain technology facilitates the creation of a transparent supply chain. (b) Digital documents, such as electronic Bills of Lading, minimize fraud, expedite transactions, and reduce bureaucratic processes. (6) Technology-Based Maritime Security – (a) Maritime cybersecurity measures to protect ship and port data from cyberattacks. (b) Modern radar systems, maritime drones, and satellites are employed to monitor the security of waters against threats such as piracy and marine pollution. (7) Green Technology and Sustainability – (a) Emission monitoring systems to support the International Maritime Organization (IMO) regulations on greenhouse gas reduction. (b) The use of environmentally friendly fuels (LNG, biofuels, hydrogen) supported by digital management systems. (8) Benefits of Technology Integration in Maritime Management: (a) Cost and time efficiency in shipping and cargo handling operations. (b) Enhanced safety through intelligent navigation systems. (c) Increased competitiveness due to the maritime industry's greater adaptability to global trends. (d) Environmental sustainability achieved through emission reduction and cleaner energy usage. (e) Facilitated global collaboration enabled by standardized digital protocols.

The Concept of Humanization in Maritime Management 5.0. Humanization in the context of Maritime Management 5.0 is an approach that places humans at the center of digital transformation in the maritime sector. While technologies such as AI, big data, IoT, blockchain, and automation play significant roles in enhancing efficiency and safety, Maritime 5.0 does not solely focus on full automation. It also ensures that human values, worker welfare, safety, and the development of human resources remain top priorities. In other words, humanization ensures that technology supports humans rather than completely replacing them. Principles of Humanization in Maritime Management 5.0: (1) People-Centered Approach : Technology is applied to augment human capabilities rather than merely replacing the workforce. For example, AI-based navigation systems still allow the ship's captain to make the final decisions. (2) Safety & Well-being : Maritime human resources benefit from the utilization of smart monitoring systems to prevent workplace accidents, monitor seafarers' health, and create safer working environments. (3) Competency Development and Digital Literacy : Maritime human resources must be equipped with new skills in data analysis, operation of digital systems, and sustainable management to effectively adapt to the 5.0 era. (4) Ethics and Social Justice :

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Technology must not create disparities. Humanization entails providing equal access to all stakeholders in the maritime industry, including seafarers, traditional fishermen, and small and medium logistics enterprises (SMEs). (5) Human–Machine Collaboration :The concept of cobotics (collaborative robotics) is adopted, where robots or automated systems assist in high-risk tasks while humans remain the primary controllers. Benefits of Humanization in Maritime Management 5.0: (1) Enhancing maritime safety by reducing human error without eliminating the human role. (2) Increasing productivity through the synergy between human intelligence and artificial intelligence. (3) Building industry trust by maintaining human-centered values throughout the digital transformation. (4) Reducing the psychological and physical burdens of seafarers through automation that supports workplace comfort. (5) Promoting sustainability by ensuring that humans play a role in aligning technological decisions with social and environmental values. Thus, humanization in Maritime Management 5.0 serves as a bridge ensuring that advanced technologies remain human-centric, making the maritime sector safer, more inclusive, sustainable, and humane.

3. Research Method

This study employs a qualitative research approach using literature review and case study methods, focusing on selected ports and maritime companies that have implemented the Smart Maritime Management 5.0 concept. This approach is chosen to gain an in-depth understanding of the integration of technologies (AI, IoT, Big Data, Blockchain) and humanization aspects (human resources, work culture, safety, and ethics) in driving economic transformation within the maritime sector (Christodoulou, A., & Cullinane, K., 2020).

Types and Sources of Data: (1) Primary Data: (a) Semi-structured interviews with port managers, maritime IT engineers, regulators, and representatives of shipping associations. (b) Direct observation at smart port facilities. (2) Secondary Data: (a) Scientific journal articles, industry reports, government policy documents, and publications from international organizations such as the IMO, UNCTAD, and OECD. (b) Statistical data from the Central Bureau of Statistics (BPS), the Ministry of Transportation, and the World Bank related to the maritime sector. (3) Data Collection Techniques: (a) Literature Review – Collecting information from scientific journals, books, and industry reports related to Maritime 5.0 technologies and humanization strategies. (b) Interviews – Exploring practitioners’ perspectives on the implementation of Smart Maritime Management 5.0. (c) Field Observation – Observing the application of smart port management systems (e.g., the use of AI for vessel scheduling or IoT for cargo tracking) (Ministry of Transportation 2024).

Analysis was conducted using the Miles and Huberman model: (1) Data Reduction: Sorting and selecting relevant data related to the integration of technology and humanization. (2) Data Display: Organizing matrices that illustrate the relationships between technology, human resources, and economic impact. (3) Conclusion Drawing: Deriving conclusions regarding the effective implementation model of Smart Maritime Management 5.0 for economic transformation. (Tseng, P. H., & Pilcher, N., 2022). Additionally, SWOT analysis is employed to identify the strengths, weaknesses, opportunities, and threats associated with the

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implementation of this concept in Indonesia.

Data Validity: To ensure validity, the following methods were employed: (1) Source Triangulation: Utilizing multiple sources (practitioners, regulators, academics). (2) Method Triangulation: Combining literature review, interviews, and observations. (3) Member Checking: Confirming interview results with the informants (UNCTA, 2023)

METODE PENELITIAN



4. Finding and Discussion

Technological Implementation in Smart Maritime Management 5.0. The findings of the study indicate that the implementation of Smart Maritime Management 5.0 in Indonesia's maritime sector has begun to materialize through the utilization of advanced technologies such as the Internet of Things (IoT), Artificial Intelligence (AI), Big Data Analytics, and Blockchain. Several major ports, including Tanjung Priok Port and Patimban Port, have adopted integrated Port Community Systems (PCS) to streamline logistics flows and minimize vessel berth times (European Commission, 2021). Data indicate that this digitalization has the potential to improve operational efficiency by 20–30% and reduce national logistics costs, which previously accounted for 23.5% of GDP, to an estimated 18–19% within the next five years (Ministry of Transportation, 2023).

Integrating Humanization into the Transformation of the Maritime Economy. The concept of Industry 5.0 emphasizes the role of humans as the center of innovation. In the maritime sector, this is translated into the form of digital literacy training for port workers, fishermen, and vessel operators. The humanization approach not only enhances technical competencies but also prioritizes the well-being of workers through flexible work systems, sensor-based workplace safety, and the empowerment of coastal communities (Pradana, Y., & Hidayat, R, 2022). A survey conducted among 120 port workers in Java and Sumatra revealed that 78% of

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respondents experienced an improvement in workplace safety, while 65% reported a more balanced workload following the implementation of technology-based systems and human-centered design (World Bank, 2022).

Impact on Economic Transformation. The integration of technology and humanization within Smart Maritime Management 5.0 has had a significant impact on the transformation of the maritime economy, including the following aspects: (1) Supply chain efficiency through real-time tracking of vessels and cargo. (2) Enhanced export-import competitiveness due to faster loading and unloading times. (3) Creation of new job opportunities in maritime technology sectors, such as automated system operators, port data analysts, and maritime AI engineers. (4) Strengthening of coastal economies through digital market access for traditional fishermen. The estimated macroeconomic impact is an increase in the maritime sector's contribution to Indonesia's GDP from 12.5% to 15–17% by 2030, provided that the implementation roadmap proceeds as planned (Ryu, H., & Lee, J, 2021).

Challenges and Recommendations. Despite the positive outcomes observed, several challenges remain that need to be addressed. (Setiawan, A., & Susanti, D., 2024): (1) Digital divide between major and minor ports. (2) Limited internet infrastructure in remote maritime areas. (3) Significant need for large-scale reskilling and upskilling of the workforce. (4) Cybersecurity and regulatory frameworks that require strengthening. The recommendations derived from this study include the following: (1) Equal distribution of digital infrastructure across all strategic ports. (2) Continuous training programs based on blended learning models for maritime human resources. (3) Development of data security regulations and a cybersecurity framework specifically for the maritime sector. (4) Multi-sector collaboration among government, academia, industry, and coastal communities.

5. Conclusion

This study employed a qualitative approach using literature review and case study methods, focusing on selected ports and maritime companies that have implemented the concept of Smart Maritime Management 5.0. The implementation of Smart Maritime Management 5.0 in Indonesia's maritime sector has begun to take shape through the adoption of advanced technologies such as the Internet of Things (IoT), Artificial Intelligence (AI), Big Data Analytics, and Blockchain. Furthermore, the concept of Industry 5.0 emphasizes the role of humans as the center of innovation. In the maritime context, this is reflected in the provision of digital literacy training for port workers, fishermen, and vessel operators, underscoring the integration of technological advancement with human-centered development.

The integration of technology and humanization in Smart Maritime Management 5.0 has had a significant impact on the transformation of the maritime economy. These impacts include supply chain efficiency, enhanced export-import competitiveness, the creation of new job opportunities, and the strengthening of coastal economies. However, this transformation is not without its challenges. Key challenges include the digital divide between major and minor ports, limited internet infrastructure in remote areas, the urgent need for large-scale reskilling and upskilling of the workforce, and the necessity to strengthen cybersecurity regulations. To

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address these issues, several recommendations are proposed: ensuring equitable distribution of digital infrastructure, implementing continuous training programs, developing comprehensive data protection regulations and a maritime-specific cybersecurity framework, and fostering multi-sector collaboration among government, academia, industry, and coastal communities.

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